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(54) **Inspection systems**

(57) An inspection system for articles e.g. shipping containers (1) comprising means e.g. X-ray source (14) for irradiating an article with ionising radiation in one direction, means e.g. fluorescent screen (18) and TV cameras (16) and (17) for monitoring the radiation passing through the article and deriving therefrom a video image, whereby an operator can inspect and/or record the pattern of radiation passing through the article. The system further comprises means (25, 26) operable to produce a signal representative of the level of radiation passing through the article (1), and means (28, 29) operable to compare the radiation representative signal with a predetermined value of that signal and to initiate irradiation and video monitoring of the article in a second direction if an unfavourable comparison exists between the actual and predetermined signals. If both monitoring operations give an unfavorable comparison the article is unsuitable for X-ray monitoring and is inspected manually.

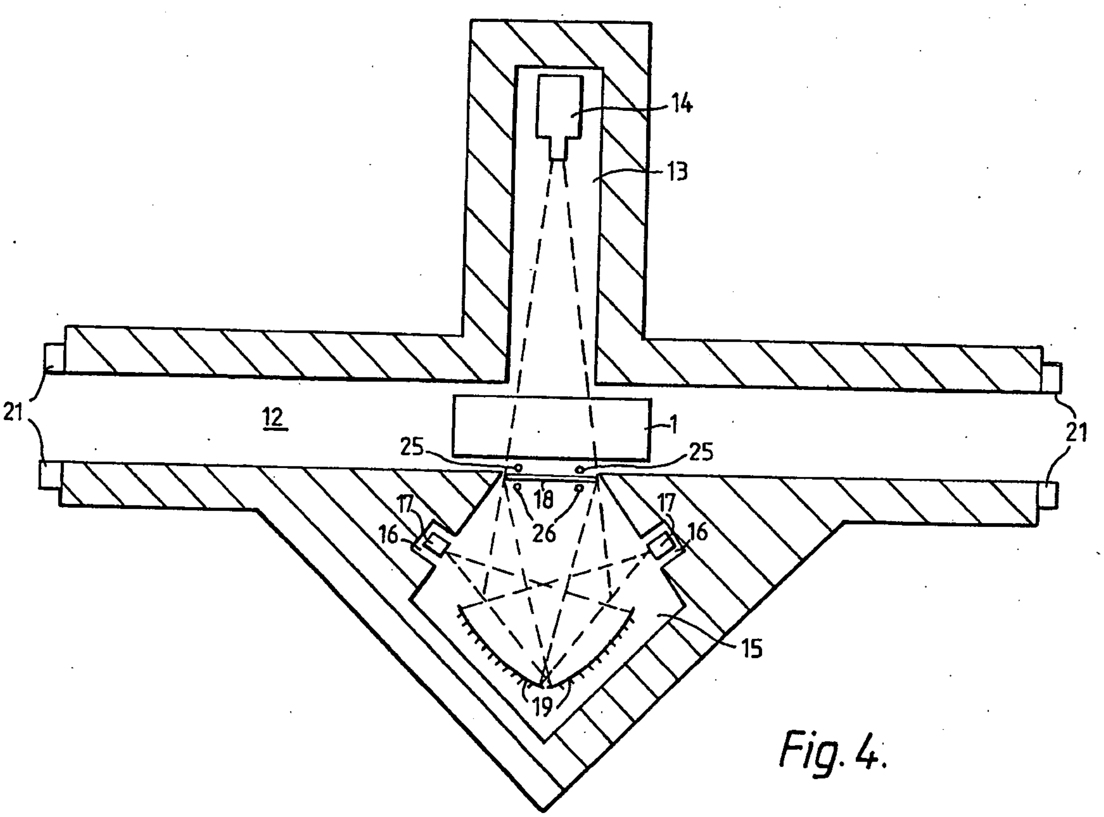

Fig. 4.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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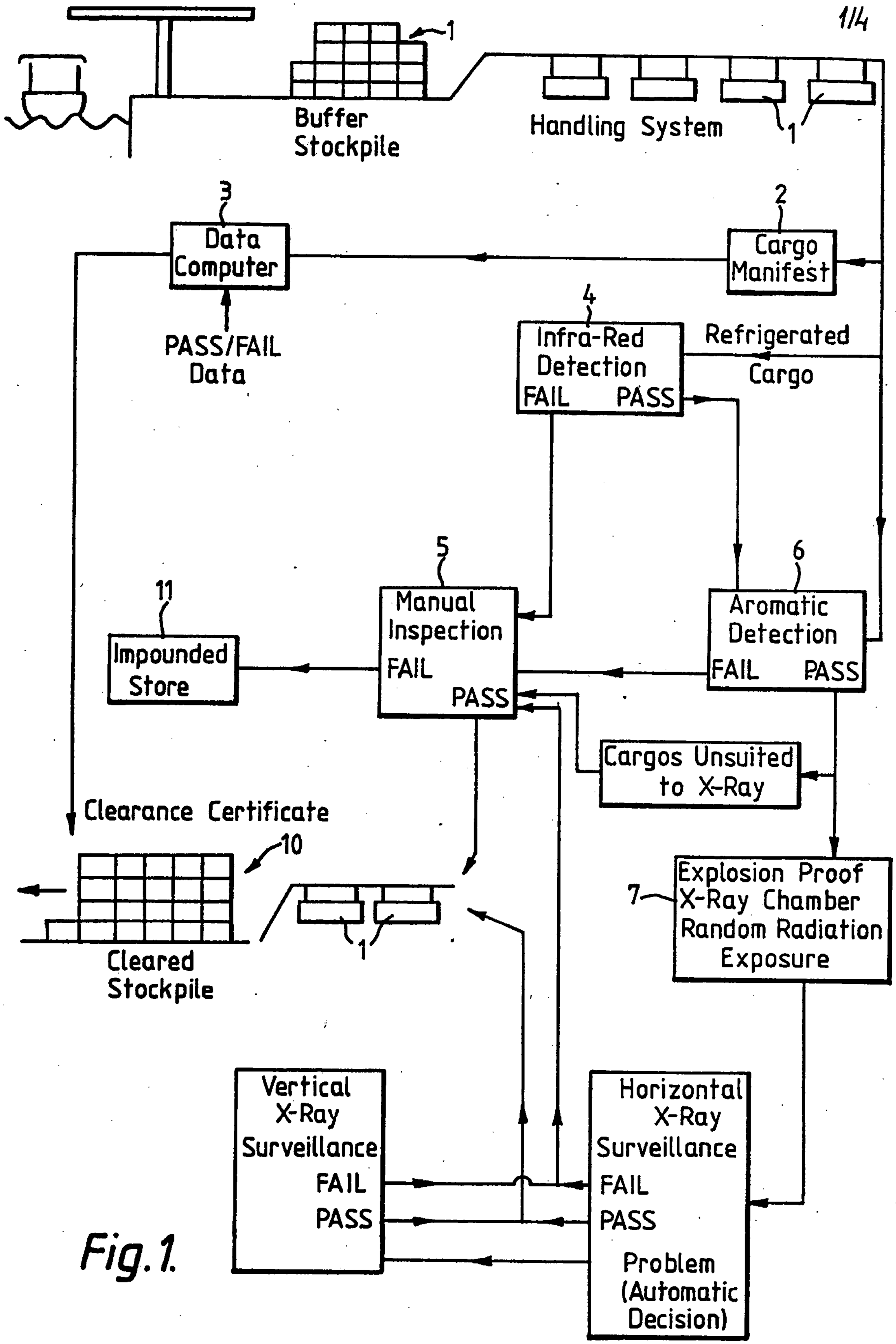
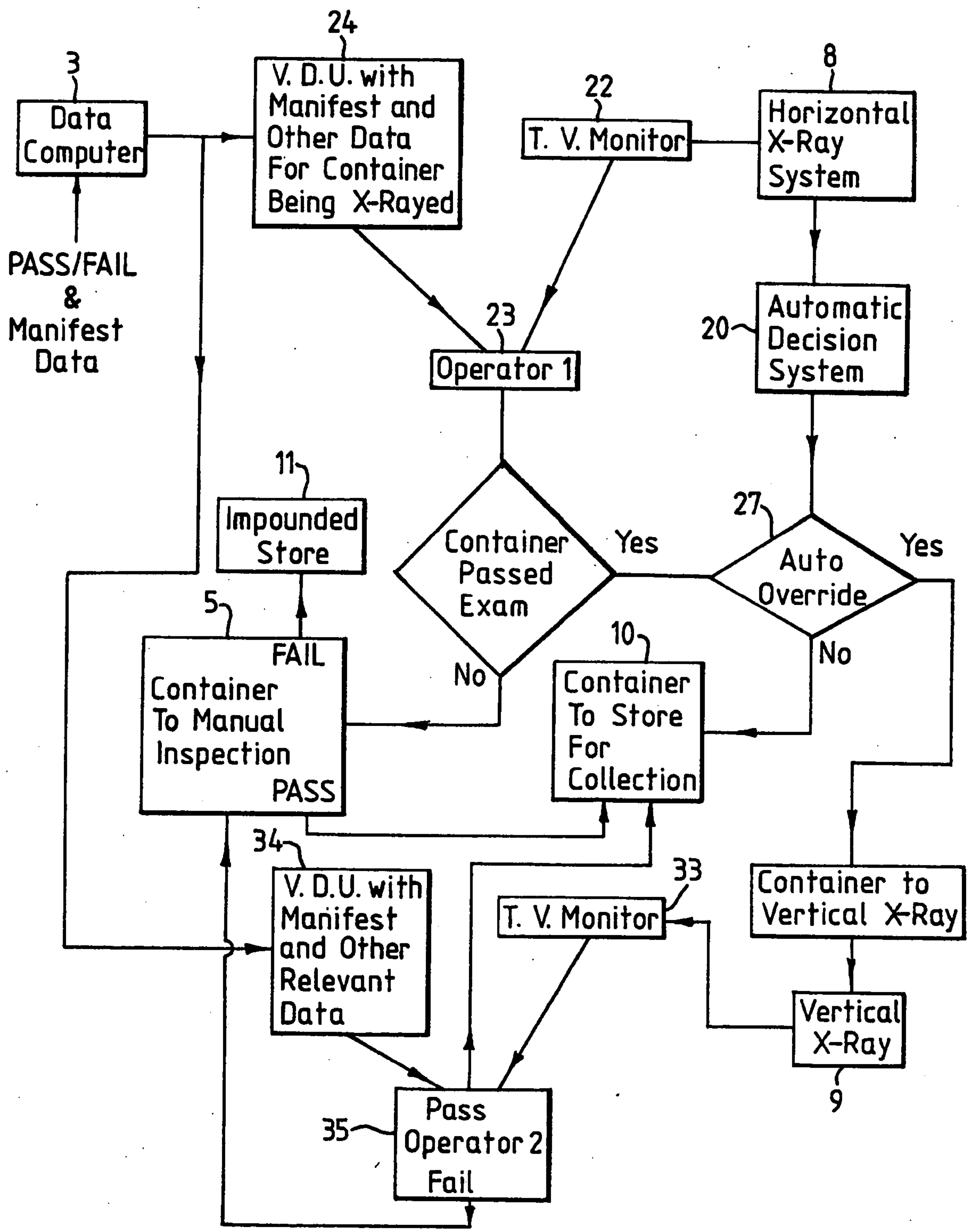


Fig. 1.



3
Data Computer
PASS/FAIL & Manifest Data
24
V. D. U. with Manifest and Other Data For Container Being X-Rayed
22
T. V. Monitor
8
Horizontal X-Ray System
23
Operator 1
20
Automatic Decision System
11
Impounded Store
Container Passed Exam
Yes
No
27
Auto Override
Yes
No
5
FAIL
Container To Manual Inspection
PASS
10
Container To Store For Collection
34
V. D. U. with Manifest and Other Relevant Data
33
T. V. Monitor
Container to Vertical X-Ray
Vertical X-Ray
9
35
Pass
Operator 2
Fail

Fig. 2.

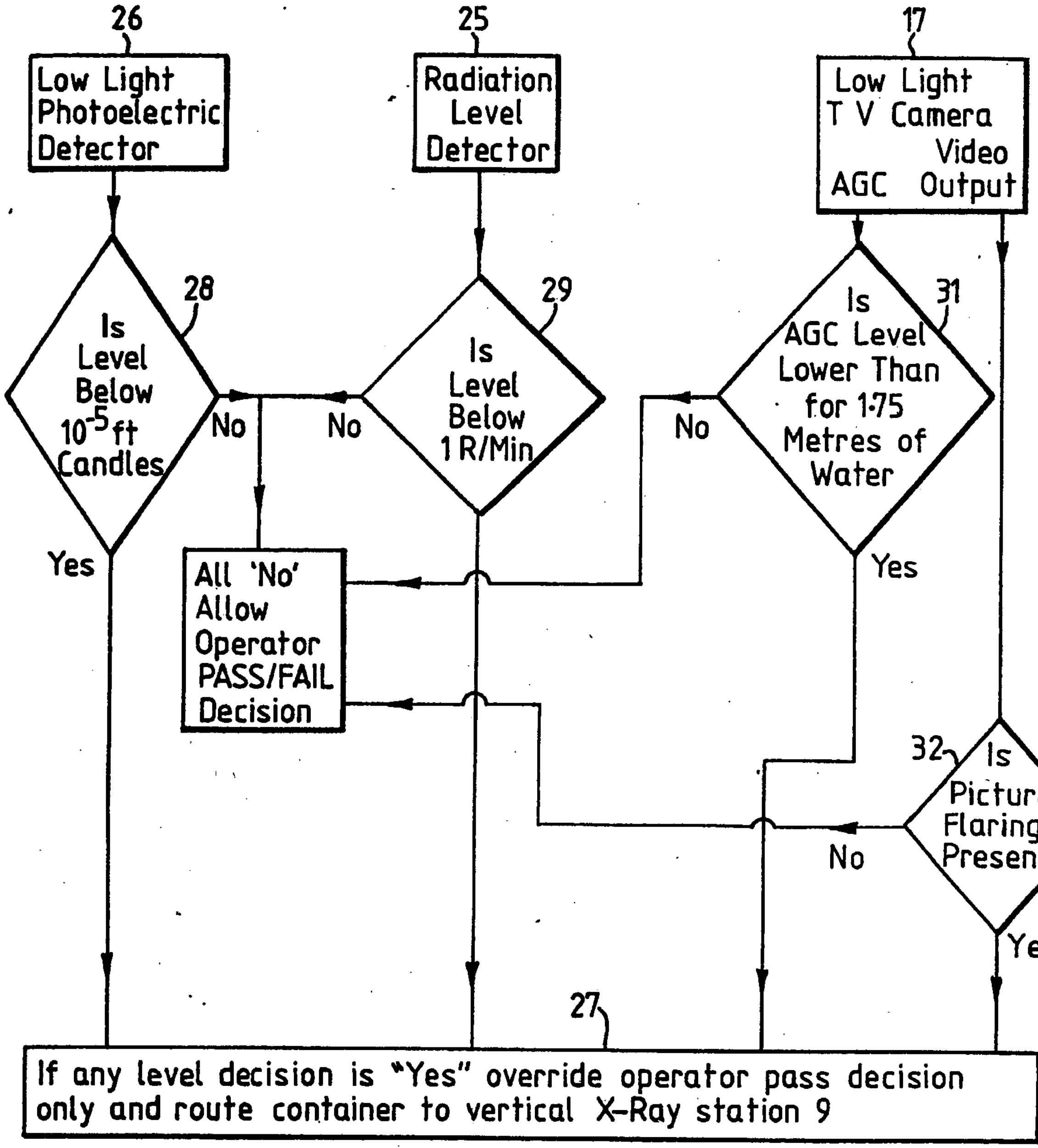

26
Low Light Photoelectric Detector
25
Radiation Level Detector
17
Low Light T V Camera
AGC
Video Output
28
Is Level Below 10^{-5} ft Candles
29
Is Level Below 1 R/Min
31
Is AGC Level Lower Than for 1·75 Metres of Water
No
No
No
Yes
Yes
All 'No' Allow Operator PASS/FAIL Decision
32
Is Picture Flaring Present
No
Yes
27
If any level decision is "Yes" override operator pass decision only and route container to vertical X-Ray station 9

Fig. 3.

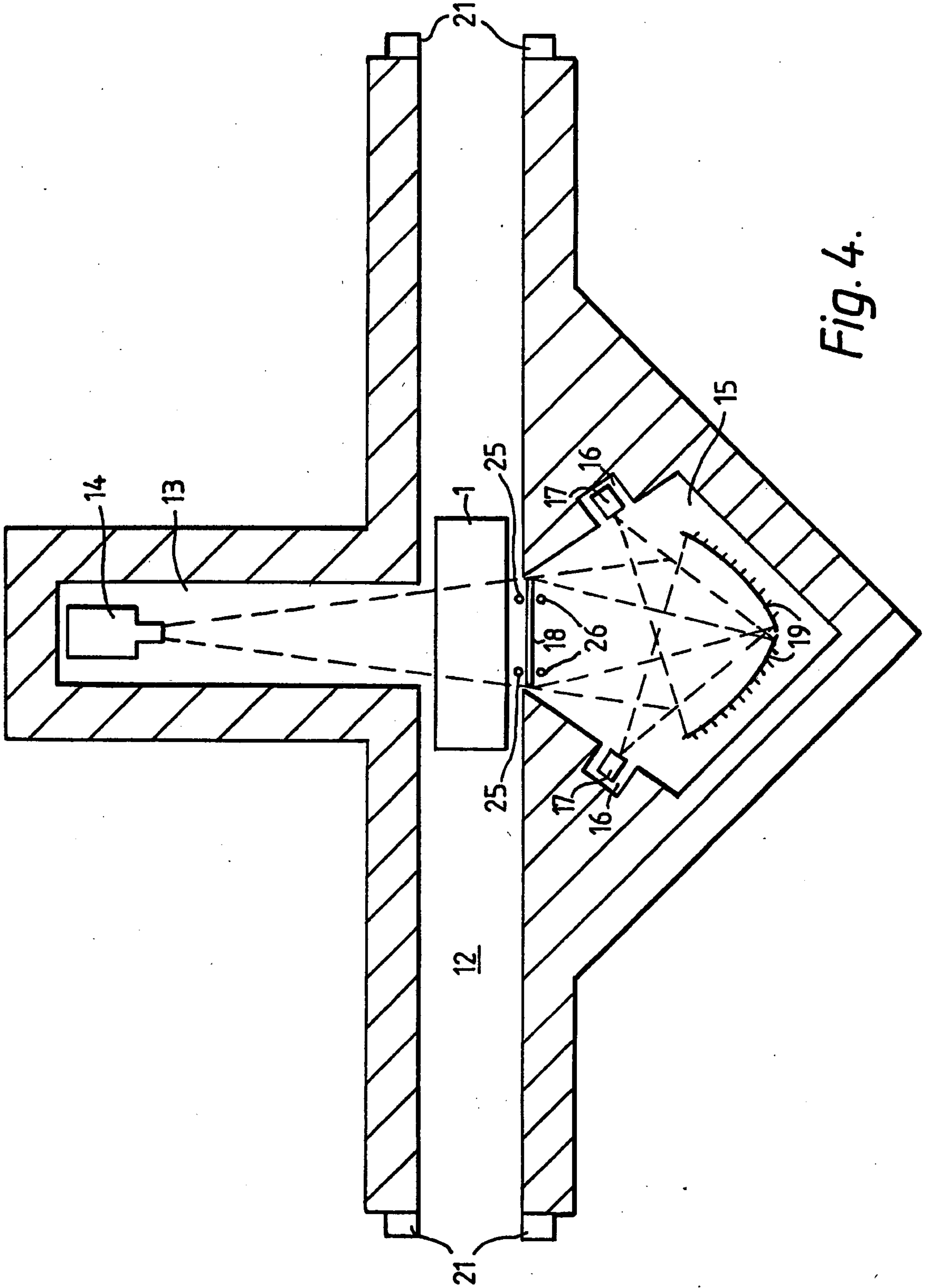


Fig. 4.

SPECIFICATION
Inspection systems

This invention relates to inspection systems and has particular, but not exclusive, reference to such systems for the large containers which are now a well-established part of merchant shipping.

One of the problems associated with these large shipping containers is that of the difficulty of inspecting the contents for customs or other purposes in an efficient and effective manner. At present, inspection has to be carried out manually which may involve a thorough check of all the contents of a container as well as the container structure, which is extremely time-consuming, or perhaps a spot check of some of the contents. In either event, the seal on the container door has to be broken which is undesirable.

The principle object of the present invention is to provide an inspection system which carries out an effective inspection of articles in the majority of cases and thereby reduces to a minimum the number of articles which have to be checked manually.

According to one aspect of the present invention there is provided an inspection system for articles comprising means for irradiating an article with ionising radiation in one direction, means for monitoring the radiation passing through the article and deriving therefrom a video image, whereby the pattern of radiation passing through the article can be inspected and/or recorded, the system further comprising means operable to produce a signal representative of the level of radiation passing through the article, and means operable to compare the radiation representative signal with a reference signal, whereby to initiate irradiation of the article with ionising radiation in a second direction relative to the article if an unfavourable comparison exists between the actual signal and the reference signal.

With such an inspection system the entire article, including the packaging where appropriate, is checked in a simple, relatively quick operation and only if it fails this inspection need it be subjected to a manual check. In the majority of cases, inspection using irradiation in the first direction will suffice to make a PASS/FAIL decision but in the case of shipping containers containing perhaps large machinery or large, dense components, it may happen that the radiation penetration thereof is insufficient to take this decision. In this event, in accordance with the invention, irradiation in the second direction is initiated which might make a PASS/FAIL decision possible if the contents are less dense in the second direction.

The first and second directions or irradiation may be generally horizontal and generally vertical, respectively. The initiation of irradiation in the second direction may be by way of re-positioning the article or re-positioning the source of radiation, by way of automatically energising second means for irradiating the article with ionising radiation, or by way of indicating to the operator that the article is to be subjected to irradiation in the second direction and/or automatically routing it to another location to this end in order not to delay the flow of articles to be subjected to irradiation in the first direction.

The means for monitoring the radiation passing through the article may be means for converting that radiation to an electrical signal from which is derived a video signal. Alternatively, the monitoring means may be means, such as a fluorescent screen, for converting that radiation to optical rays which are then focussed on to one or more television cameras which provide a video signal.

The means operable to produce a signal representative of the level of radiation passing through the article in the first direction, and which may also be provided in relation to the radiation passing through the article in the second direction, may comprise radiation detector means disposed in the path of the radiation passing through the article. When the monitoring means comprise means for converting the radiation to optical rays which are sensed by one or more TV cameras, then the means operable to produce a signal representative of the level of radiation passing through the article may comprise photo-electric detector means disposed in the path of the optical rays or said signal may be derived from the or each TV camera by means monitoring the level of the automatic gain control, or means monitoring the video output signal, for example, the extent of the automatic gain control and the video signal level both being representative of the radiation passing through the article inasmuch as the light rays produced by the conversion means and detected by the or each TV camera are a function of that radiation.

According to another aspect the invention provides an inspection system for articles comprising means for subjecting selected articles to infra-red radiation, means for subjecting the articles to aromatic analysis, means for subjecting selected articles to irradiation by ionising radiation, and data recording means to which the results of the inspection by each of said means are passed, together with data concerning the manifest of each article, the failure of an article to pass inspection by any of said means being indicated, whereby action can be taken to subject that article to manual inspection.

The system according to either aspect of the invention preferably further includes means for subjecting an article to random ionising radiation prior to being subjected to the other ionising radiation in order to trigger any sabotage device contained in the article and sensitive to ionising radiation. This random irradiation of the articles needs to be carried out in an explosion-proof chamber.

The ionising radiation may be X-ray or gamma radiation, the former being preferred.

An inspection system in accordance with the present invention will now be described in greater

detail, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic block diagram of the overall system,

Figure 2 is a more detailed block diagram of a portion of the system of Figure 1,

Figure 3 is a more detailed block diagram of a portion of Figure 2, and

Figure 4 is a schematic plan view of part of the system.

Considering first the overall system shown in Figure 1, it is designed to handle shipping containers 1 the dimensions of which are typically 2.4 metres high, 2.4 metres wide and 6 metres or 12 metres long, and which are of rigid, metal construction. The containers normally have seals on the doors and are accompanied by a manifest which thus provides details of the alleged contents. The system is intended to carry out an effective and expeditious inspection of containers 1 to check for contraband.

The containers 1 are stockpiled on the quay and are then taken through the inspection system by an automatic handling system. First the cargo manifest of each container 1 is converted to digital format at 2 for recording in the memory of a computer 3 and the container is given a unique coding (for example a magnetic signature). If the container is of the refrigerated type, it is first subjected to infra-red radiation at 4 and the reflected radiation checked so as to be able to detect any hot spots which might mean the existence of contraband in the thermal insulation of the container. If a container fails this test, it is sent for manual inspection at 5. If it passes the infra-red test, the container is sent for aromatic analysis at 6. Here a sample of the air within the container is taken and examined for traces of contraband by a trace atmospheric gas analyser. If the container fails this test, it is sent for manual inspection at 5 but if it passes, it is sent for inspection by X-ray radiation unless the contents are known to be unsuitable for such inspection (for example livestock of photographic supplies) in which case it is sent for manual inspection.

The X-ray inspection is split into three parts, the first being indicated at 7 and being in the form of an explosion-proof chamber into which the container is taken and subjected to random X-ray radiation both as regards intensity and duration. This is with a view to triggering any sabotage device concealed in the container and which is sensitive to X-ray radiation. Any container which survives this test is sent to the second part of the X-ray inspection indicated at 8. Here the container is subjected from one side to a comparatively high level of X-ray radiation in a generally horizontal plane, the radiation passing through the container being monitored on the opposite side as will be discussed in greater detail hereinafter. If the container passes this test, it is sent to a stockpile 10 of cleared containers to await transportation to its destination, otherwise the container is sent for manual inspection at 5.

If the level of radiation passing through the container is insufficient to determine whether contraband might be present, the container is sent to the third part of the X-ray inspection which is indicated at 9. Here, the container is irradiated with X-ray radiation as at 8 but in a different direction (namely generally vertically) as the size and disposition of the container contents may enable a positive inspection to be made in this direction. If this is so and the container passes the test, it is sent to the stockpile 10 of cleared containers. If the test is failed, or if it is still impossible to make a positive decision, the container is sent for manual inspection at 5.

The results of the tests at the various stations are sent to the computer 3 which issues a clearance certificate as appropriate. Any container found to carry contraband is impounded at 11.

Referring now to Figures 2 to 4, the horizontal X-ray inspection effected at 8 will now be described in greater detail. The inspection is carried out in a protected environment, Figure 4 showing concrete radiation barriers which define a passageway 12 through which each container 1 to be inspected moves, a chamber 13 housing a linear accelerator 14 operable to produce X-ray radiation to the required level, the chamber being open at one end at which the container under inspection is located, and a chamber 15 which has an opening facing that of the chamber 13. The chamber 15 has two recesses 16 each of which contains a low light TV camera 17 which is protected by the recess from direct X-ray radiation. The opening in the chamber 15 is closed by imaging target means or electro-optic converter means in the form of a fluorescent screen 18 which measures approximately 2.4 metres by 3.7 metres. The screen 18 converts the X-ray radiation passing through the container into optical rays which are focussed by a pair of curved mirrors 19 onto the respective cameras 17. At each end of the passageway 12 a pair of infra-red detectors 21 are located which operate to detect the presence of personnel and inhibit operation of the linear accelerator 14 if personnel are present.

The TV cameras 17 produce video output signals which are taken to a TV monitor 22 located at an operator station 23 (Figure 2) at which is also located a visual display unit (VDU) 24 associated with the computer 3 and showing the cargo manifest and other data associated with any container under inspection.

If the contents of a container are such as to allow sufficient X-ray penetration to provide a good picture on the TV monitor 22 to enable the operator to make a positive PASS or FAIL decision then there is no difficulty. However, if insufficient radiation passes through the container to this end, it is important to be aware of this and an automatic decision system 20 is provided for this purpose. This system comprises four sensor means and Figure 4 shows two sensors, the first sensor of which is in the form of a plurality of radiation detectors 25 disposed on the side of the screen 18 facing the linear accelerator 14. The second sensor is in the form of a plurality of

photo-electric detectors 26 located on the side of the screen 18 opposite to that with which the radiation detectors are associated.

Looking now at Figure 3, two further "sensors" are illustrated, one being associated with the automatic gain control (AGC) of the TV cameras 17 and the other with the video output of the cameras. More specifically, the video signal outputs of the cameras 17 are monitored in respect of "flaring" on the TV monitor 22 which is a condition in which the boundary between two areas of contrast is indistinct or "fuzzy". This monitoring can be effected electronically.

Figure 3 shows the use of all four types of sensors discussed but it should be appreciated that it is not necessary to employ more than one inasmuch as all provide an output signal which is representative of the level of radiation passing through a container. Figure 3 shows the outputs of the sensors being applied to some form of comparator the output signals from which either allow the operator to make a PASS/FAIL decision or will actuate an automatic override 27.

The output signals from the photo-electric detectors 26 are applied to a comparator 28 to which is also applied a reference signal representative of a specific light level, for example 10^{-5} foot candles. If the input light level is below the reference level, then a signal is sent to the automatic override 27. Likewise, the radiation detectors 25 are associated with a comparator 29 to which is also applied a reference signal representative of a specific level of radiation, for example 1 Rad per minute, below which the operator is likely to have sufficient clarity in the TV picture to make a positive decision. If the radiation level is below this reference level, then again a signal is sent to the automatic override 27. The AGC of the TV cameras 17 is monitored by a comparator 31 against a gain which would be present in respect of a specific object being subjected to a predetermined level of radiation, for example 1.75 metres of water. Again, if the comparison is unfavourable, a signal is sent to the automatic override 27. Finally, the presence or otherwise of picture flaring is monitored at 32 and if present, a signal is sent to the override 27. The presence of one or more signals at the override 27 will automatically result in the container under inspection being sent to a second X-ray facility 9 which is generally similar to that shown in Figure 4 but having the linear accelerator and fluorescent screen arranged for a vertical X-ray scan. If the results of the comparisons made at 28, 29, 31 and 32 are all favourable then the operator is able to make a PASS/FAIL decision which will not be overridden.

The second X-ray facility 9 also has a TV monitor 33 (Figure 2) and a VDU 34 connected to the computer 3. The operator at 35 makes a PASS/FAIL decision and the container is either sent to the cleared stockpile 10 or for manual inspection, as appropriate. If the operator is unable to make a decision because the clarity of the picture is deficient for the same, or other, reasons as those which resulted in the container being sent to the second X-ray facility 9, then a FAIL decision should be made so that a manual inspection can be carried out. Clearly, the second X-ray facility 9 can be provided with an automatic decision system similar to the system 20 of the first facility 8 even though this has not been shown in Figure 2. In this way, the operator is unable to make a PASS decision when the circumstances do not warrant it as regards the information discernible from the picture on the TV monitor.

In both of the X-ray facilities 8 and 9, a container 1 is inspected in stages inasmuch as the linear accelerator 14 and screen 18 are only able to inspect a "slice" of the container at a time, each slice being a rectangle measuring approximately 2.4 metres by 2.4 metres. To accommodate this, each container is moved progressively past the opening in the chamber 13. Also, each X-ray facility 8, 9 may be provided with a video recorder so that a recording can be made of each X-ray inspection, perhaps for monitoring subsequently if the operator is temporarily otherwise occupied.

It will be appreciated that the illustrated inspection system effects a comprehensive inspection of the containers in an efficient manner and minimises the number of containers which have to be subjected to manual inspection. The most important feature of the system is the automatic decision system 20 which ensures that if the picture on the TV monitor is of a quality such that a positive PASS decision cannot be made, then the container is subjected to X-ray radiation in another direction to see whether this enables a positive PASS to be made before the time-consuming manual inspection is called up.

The illustrated system employs a separate X-ray facility 9 for this second X-ray inspection in order not to delay the flow of containers through the first X-ray facility 8. However, if this delay can be tolerated, the facility 8 can be provided with a second linear accelerator, fluorescent screen and TV cameras so as to effect an X-ray scan in a generally vertical, or other desired, direction. Alternatively, the container under inspection could be rotated through 90° and the same linear accelerator 14 and associated components used. In a further alternative arrangement, the same linear accelerator is again used for both scans but this time the container is kept stationary and the linear accelerator and screen are moved.

CLAIMS

1. An inspection system for articles comprising means for irradiating an article with ionising radiation in one direction, means for monitoring the radiation passing through the article and deriving therefrom a video image, whereby the pattern of radiation passing through the article can be inspected and/or recorded, the system further comprising means operable to produce a signal representative of the level of radiation passing through the article, and means operable to compare the radiation representative signal with a

reference signal, whereby to initiate irradiation of the article with ionising radiation in a second direction relative to the article if an unfavourable comparison exists between the actual signal and the reference signal.

2. A system according to claim 1, wherein the means for monitoring the radiation passing through the article are means for converting that radiation to an electrical signal from which is derived a video signal.

3. A system according to claim 1, wherein the means for monitoring the radiation passing through the article are means for converting that radiation to optical rays which are focussed on to one or more television cameras operable to provide a video signal.

4. A system according to claim 3, wherein said converting means are in the form of a fluorescent screen.

5. A system according to any of the preceding claims, wherein the means operable to produce a signal representative of the level of radiation passing through the article include radiation detector means disposed in the path of that radiation.

6. A system according to claim 3 or 4, wherein the means operable to produce a signal representative of the level of radiation passing through the article include photo-electric detector means disposed in the path of the optical rays emanating from said converting means.

7. A system according to any of claims 3, 4 and 6, wherein the means operable to produce a signal representative of the level of radiation passing through the article include means for monitoring the level of the automatic gain control of the or each television camera.

8. A system according to any of claims 3, 4, 6 and 7, wherein the means operable to produce a signal representative of the level of radiation passing through the article include means for monitoring the video output signal of the or each television camera.

9. A system according to any of the preceding claims, wherein irradiation of the article in said second direction is effected by second means for irradiating the article with ionising radiation.

10. A system according to claim 9, wherein the second means for irradiating the article with ionising radiation is remote from the other irradiating means and the system also includes means for routing the article to said second irradiating means.

11. A system according to any of claims 1 to 8, wherein irradiation of the article in said second direction effected by either re-positioning the article relative to the means for irradiating the article with ionising radiation, or by re-positioning the latter relative to the article.

12. A system according to any of the preceding claims and further comprising data recording means to which are passed the results of the inspection by radiation of each article, the data recording means also having recorded therein data concerning the manifest of each article, which data is available to the operator of the system.

13. An inspection system for articles comprising means for subjecting selected articles to infra-red radiation, means for subjecting the articles to aromatic analysis, means for subjecting further selected articles to irradiation by ionising radiation, and data recording means to which the results of the inspection by each of said means are passed, together with data concerning the manifest of each article, the failure of an article to pass inspection by any of said means being indicated, whereby action can be taken to subject that article to manual inspection.

14. A system according to any of the preceding claims, wherein means are provided for irradiating an article with random ionising radiation prior to irradiating the article with said ionising radiation.

15. A system according to any of the preceding claims, wherein the ionising radiation is X-ray radiation.

16. A system according to any of claims 1 to 14, wherein the ionising radiation is gamma-ray radiation.

17. A system according to any of the preceding claims, wherein the articles are routed through the system by an automatic handling system.

18. An inspection system substantially as herein particularly described with reference to the accompanying drawings.

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